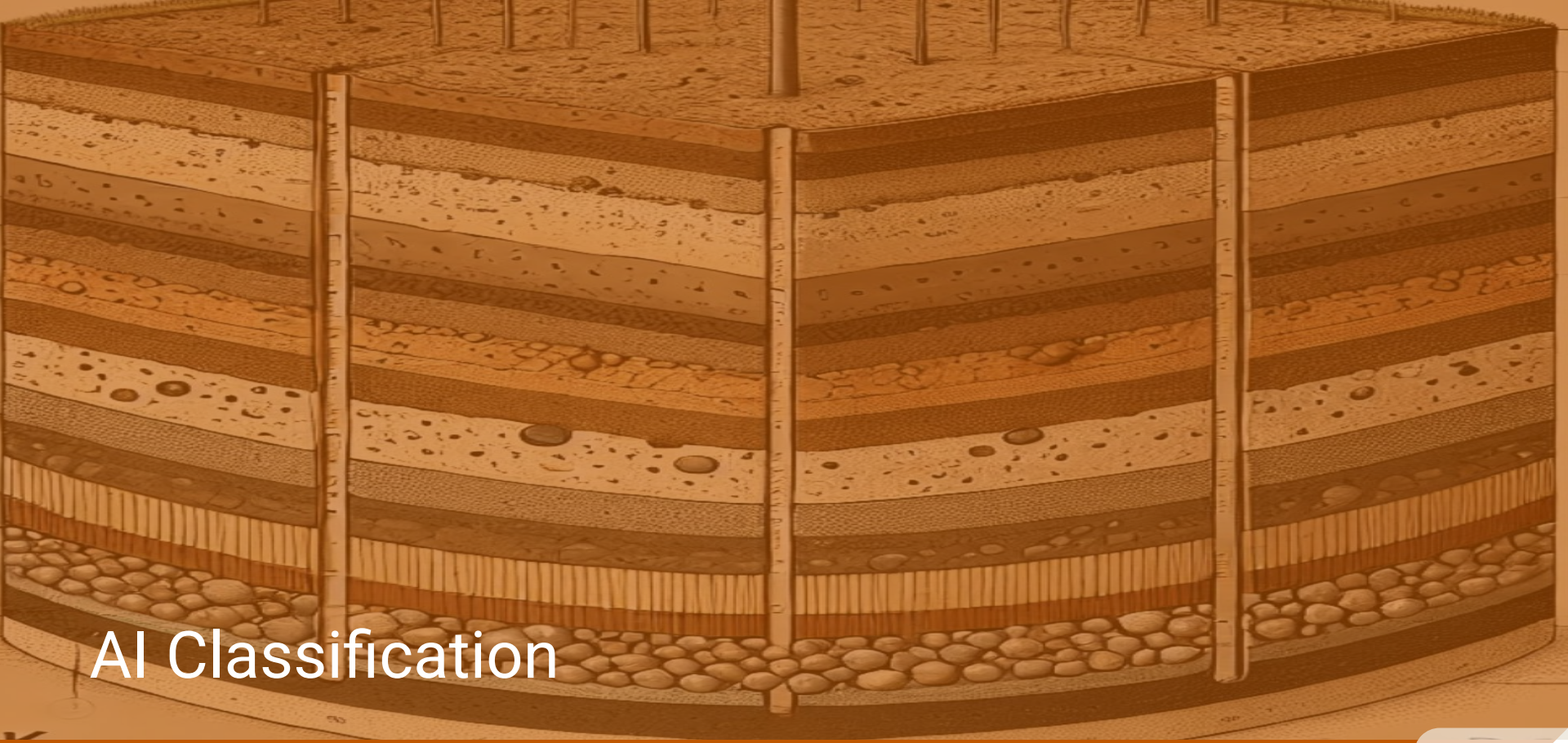


AI Classification

Krishna Kumar, UT Austin

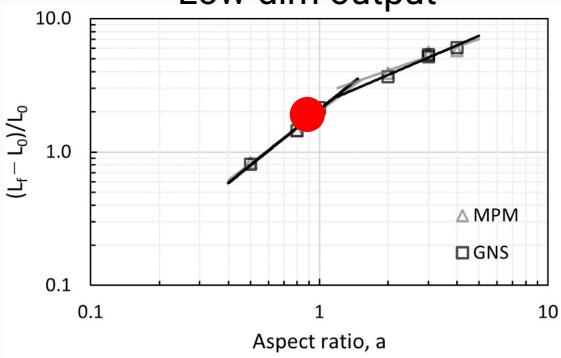
Why I dislike ML?

Input parameters

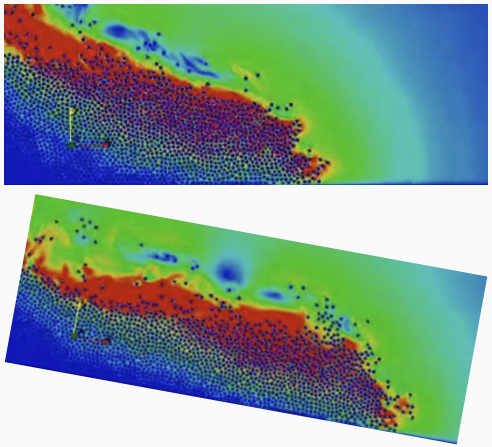
```
density = 1800 kg/m3
      n = 0.4
Aspect ratio = 0.8
   Slope = 2.5°
```

Magical NN

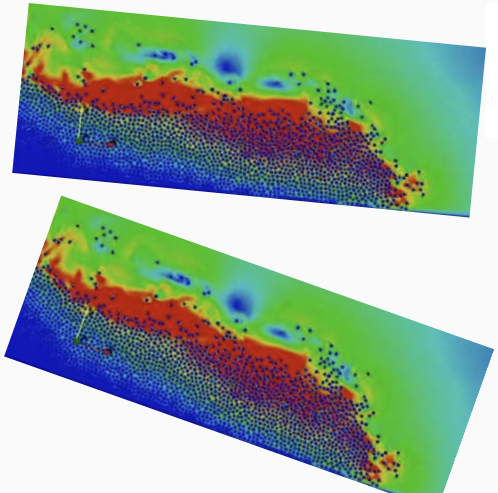
Low-dim output



Training



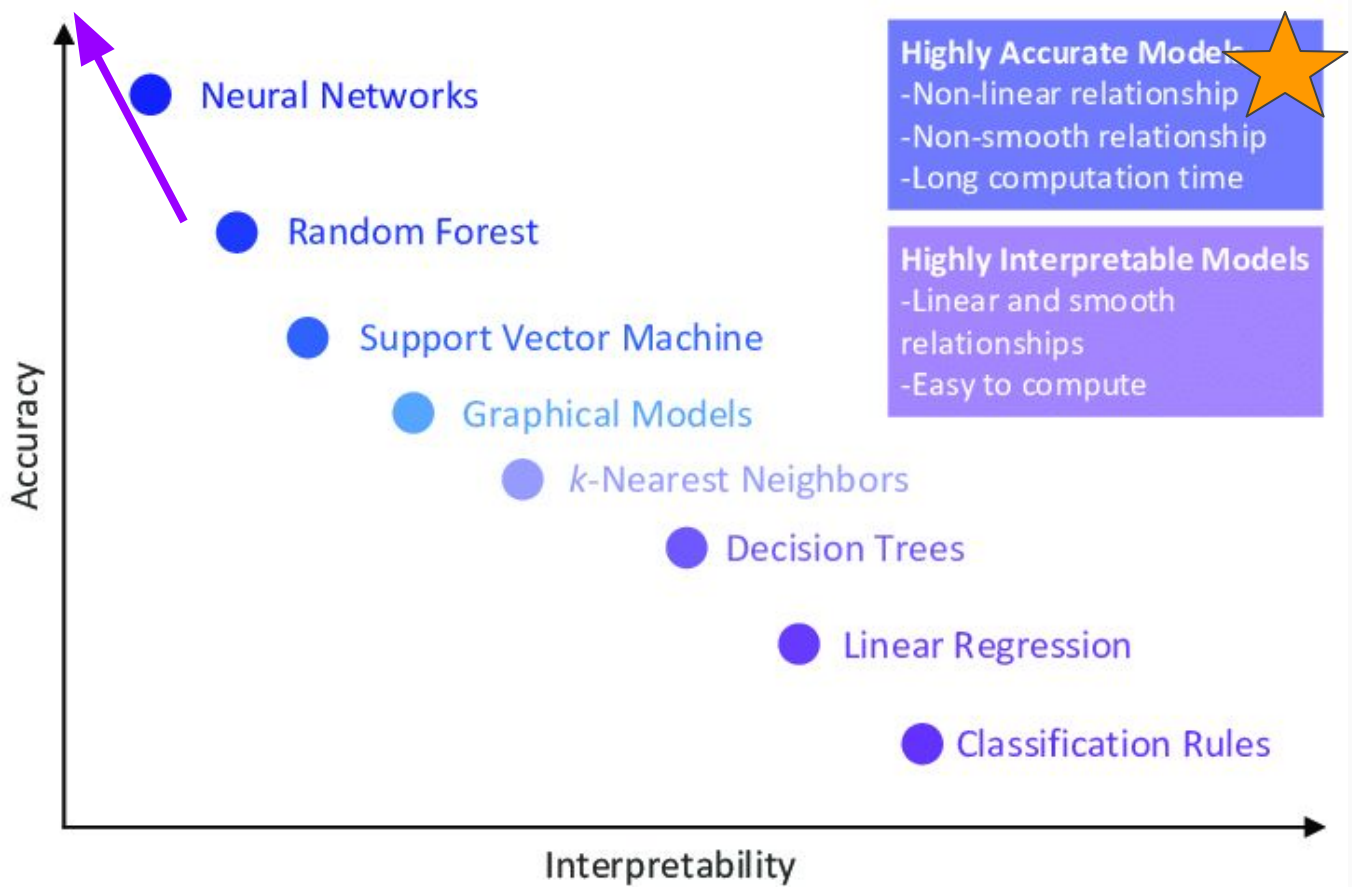
Testing



Interpolate

Extrapolate

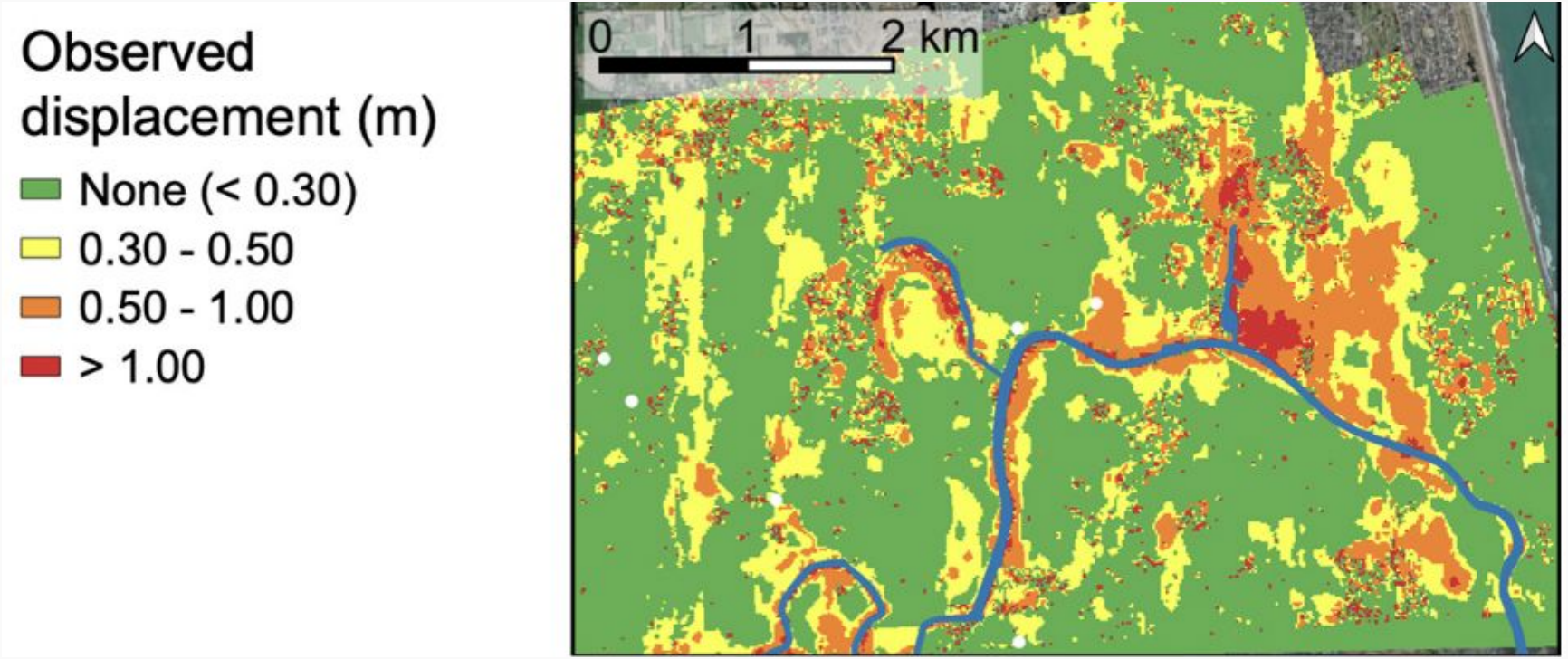
Interpretability vs accuracy



Lateral Spreading

Decision Trees & Random Forest

Predicting lateral spreading in NZ



Durante and Rathje, 2021

Predicting lateral spreading in NZ

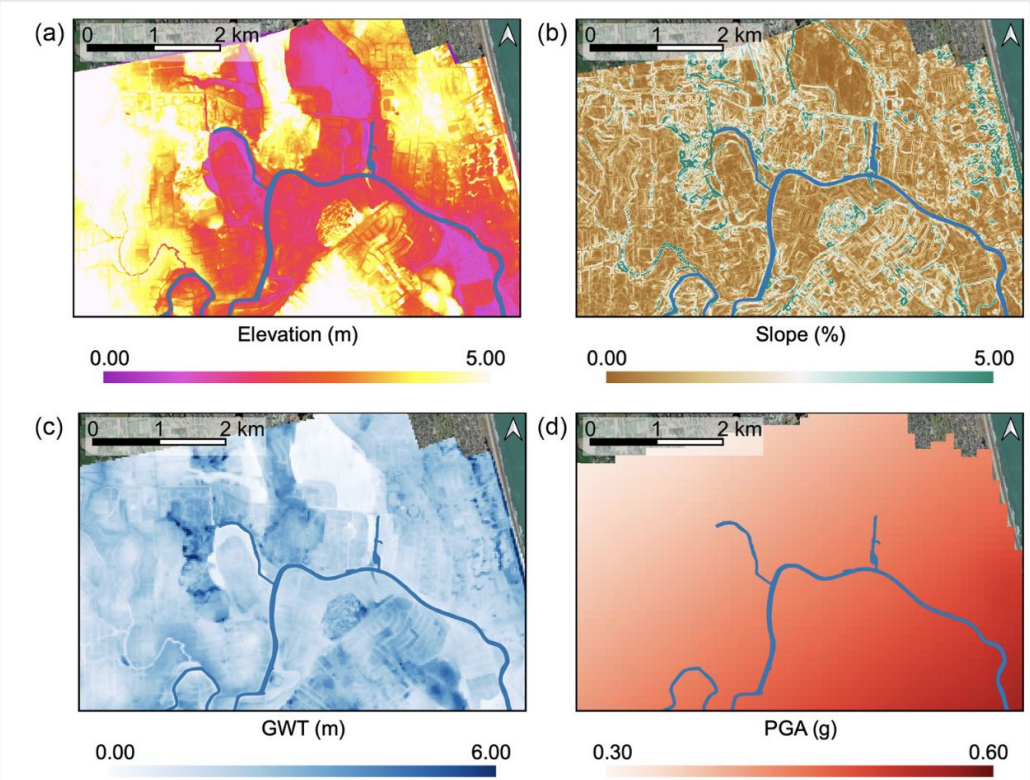
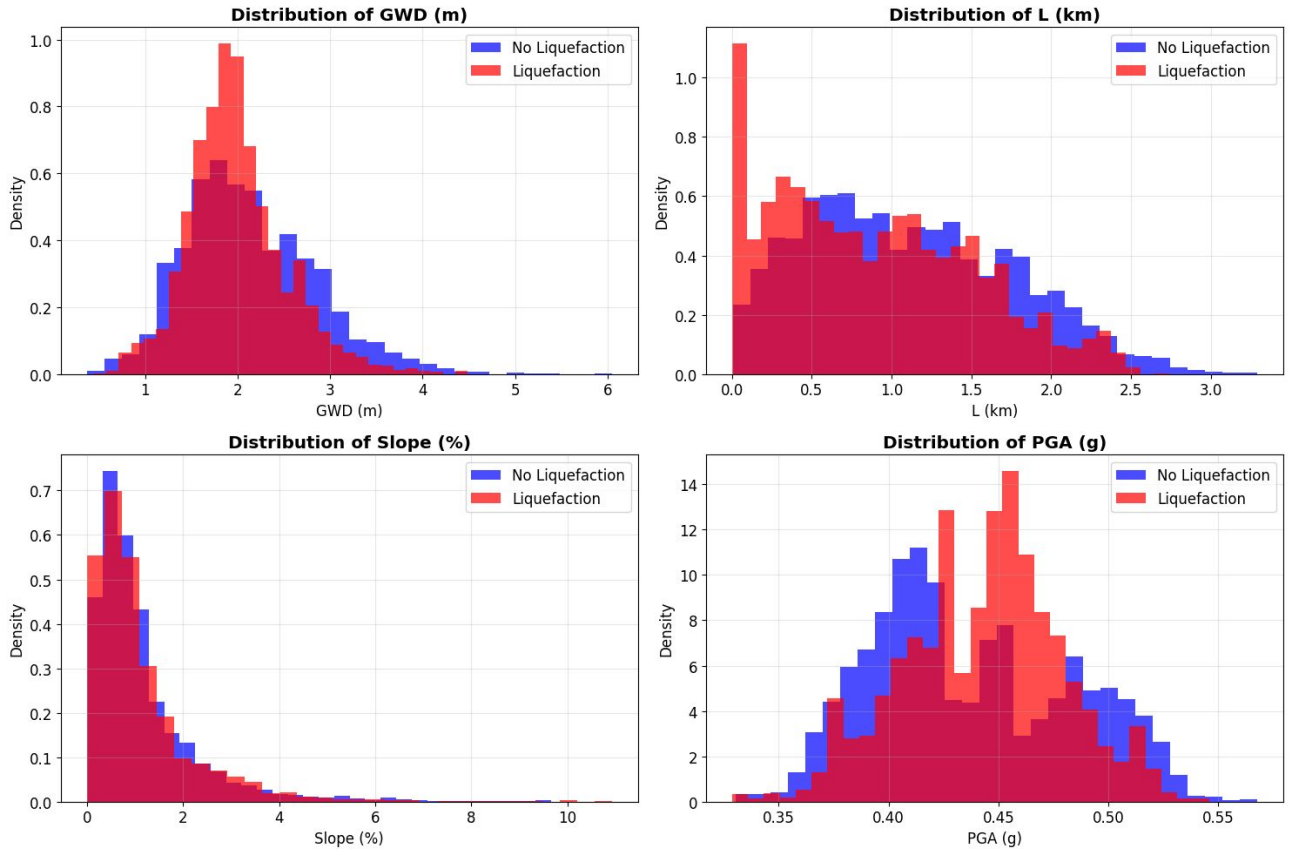


Figure 4. Spatial distribution of geometric and event-specific input features considered in ML models: (a) ground elevation, (b) ground slope, (c) GWT depth, and (d) PGA.

Durante and Rathje, 2021

Distribution of data



Random Forest model

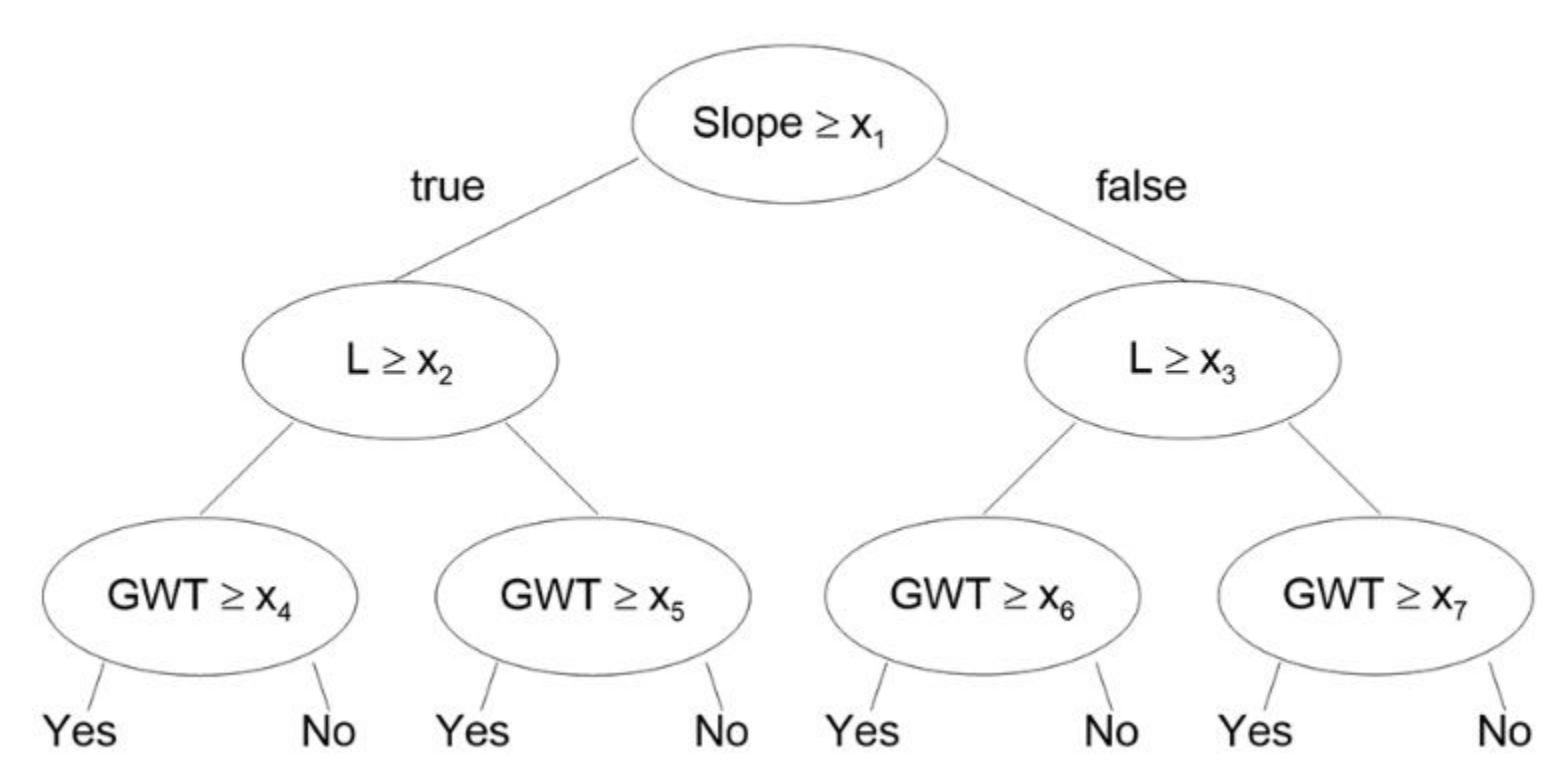
Table 3. Summary of features used in each RF model analyzed

		Feature					
		L (m)	GWT (m)	Slope (%)	PGA (g)	Elevation (m)	CPT data
No CPT data	Model 0	✓	✓	✓	○	○	○
	Model 1	✓	✓	✓	✓	○	○
	Model 2	✓	✓	✓	○	✓	○
	Model 3	✓	✓	✓	✓	✓	○
CPT data	Model 4	✓	✓	✓	✓	○	✓
	Model 5	✓	✓	✓	✓	✓	✓

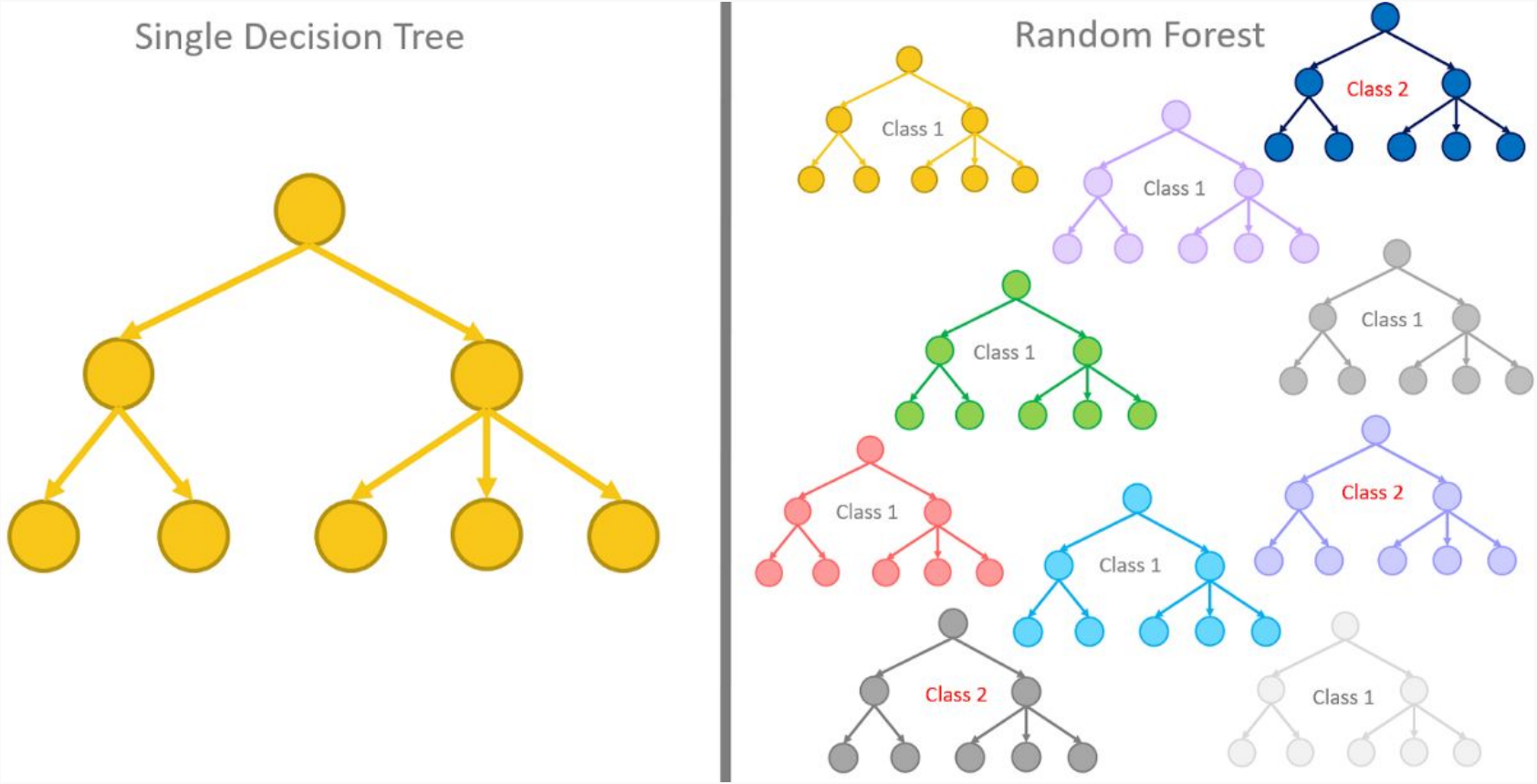
GWT: ground water table; PGA: peak ground acceleration; CPT: cone penetration tests.

Durante and Rathje, 2021

Classification - Decision Tree



Random Forest



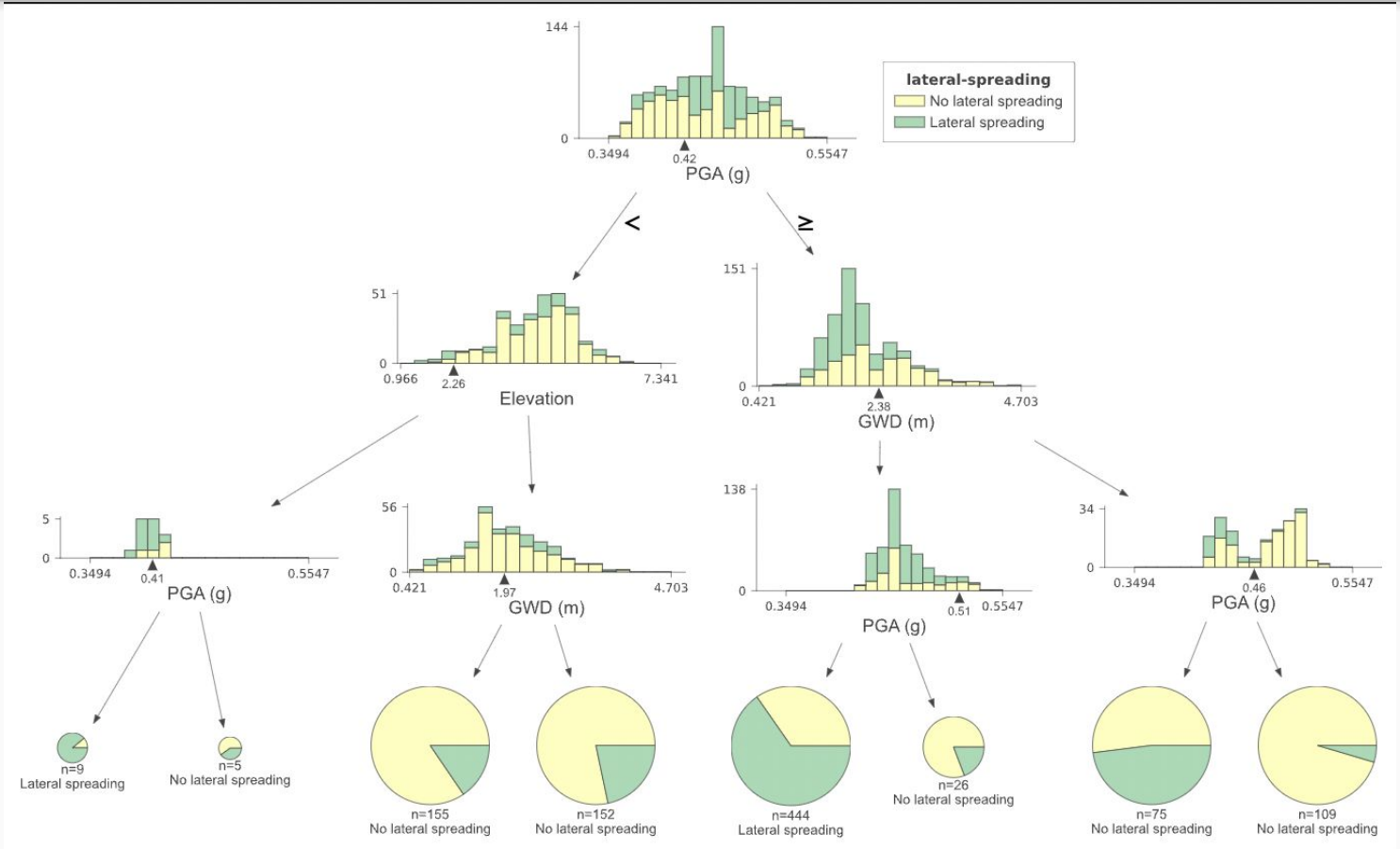
Random Forest - Performance

Table 4. Evaluation metrics for RF models for Yes/No and displacement classification problems

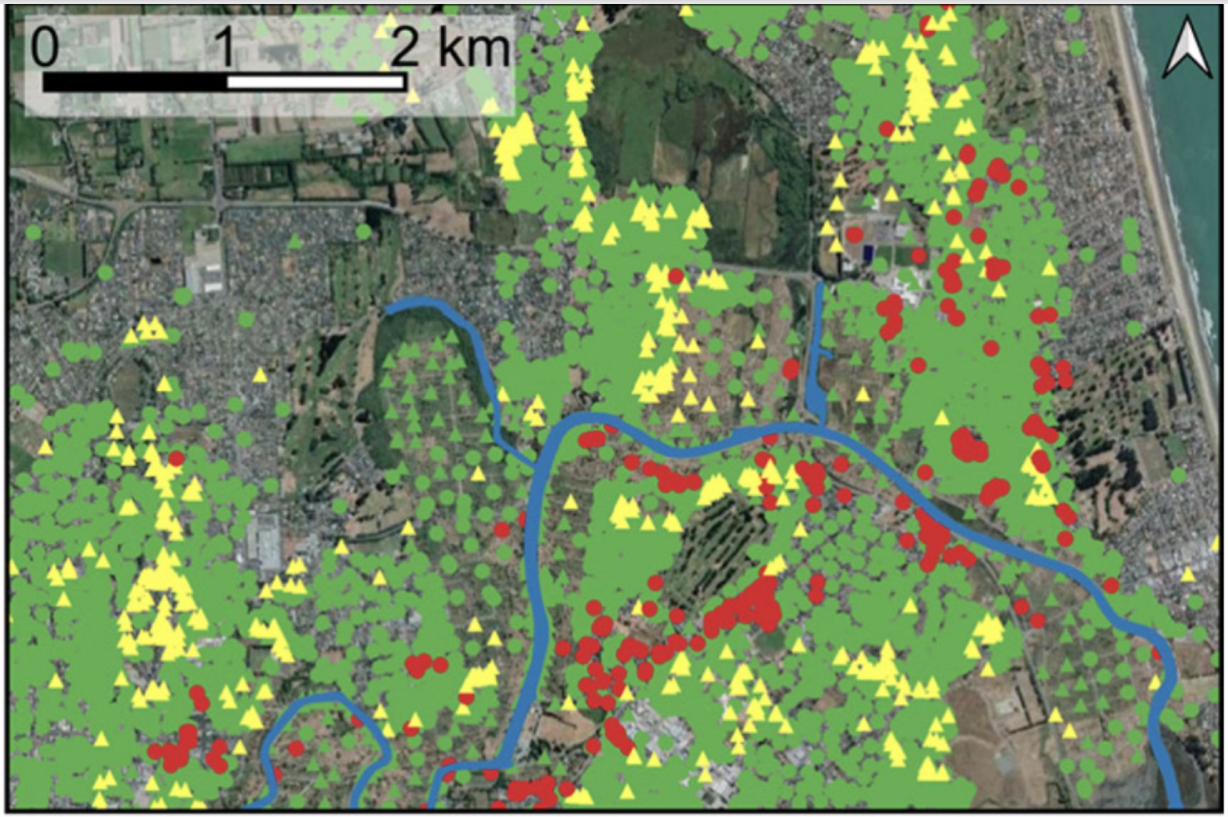
		No CPT data				CPT data	
		Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Y/N	Accuracy (Overall)	0.76	0.85	0.82	0.88	0.85	0.87
	Recall—Yes	0.58	0.75	0.74	0.82	0.76	0.78
	Recall—No	0.90	0.92	0.88	0.93	0.92	0.93
	Precision—Yes	0.80	0.88	0.82	0.89	0.87	0.89
	Precision—No	0.75	0.84	0.83	0.87	0.84	0.85
	ROC AUC	0.76	0.88	0.84	0.90	0.86	0.88
DISPL	Accuracy (Overall)	0.78	0.88	0.86	0.89	0.88	0.89
	Recall—Class 0	0.88	0.91	0.93	0.92	0.91	0.91
	Recall—Class 1	0.67	0.87	0.79	0.89	0.88	0.90
	Recall—Class 2	0.27	0.42	0.33	0.42	0.53	0.49
	Precision—Class 0	0.79	0.90	0.86	0.92	0.90	0.92
	Precision—Class 1	0.74	0.84	0.84	0.85	0.85	0.84
	Precision—Class 2	0.97	0.98	0.97	0.94	0.95	0.93
	ROC AUC	0.82	0.89	0.87	0.90	0.86	0.88

CPT: cone penetration tests; ROC: receiver operating characteristic; AUC: area under the ROC curve; Y/N: Yes/No Classification problem; DISP: Class Displacement Classification problem.

Visualizing the first tree in RF



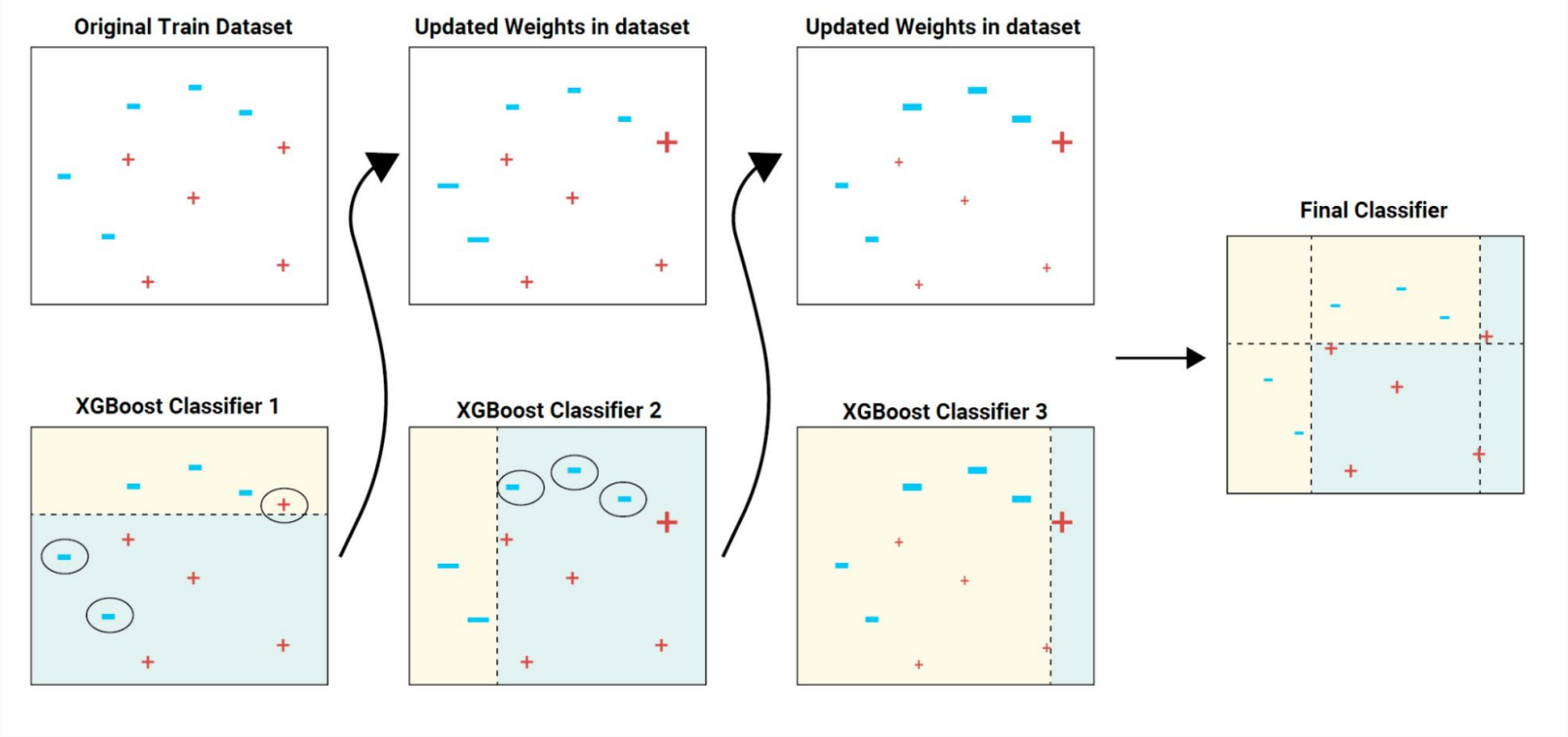
Random forest prediction of lateral spreading



Durante and Rathje, 2021

▲ True Positive (TP) ● True Negative (TN) ● False Positive (FP) ▲ False Negative (FN)

Extreme Gradient Boosting



SHAP Value: Contribution of each variable

A: $v(\{A\}) - v(\{\}) = 10 - 0 = 10$

B: $v(\{A,B\}) - v(\{A\}) = 60 - 10 = 50$

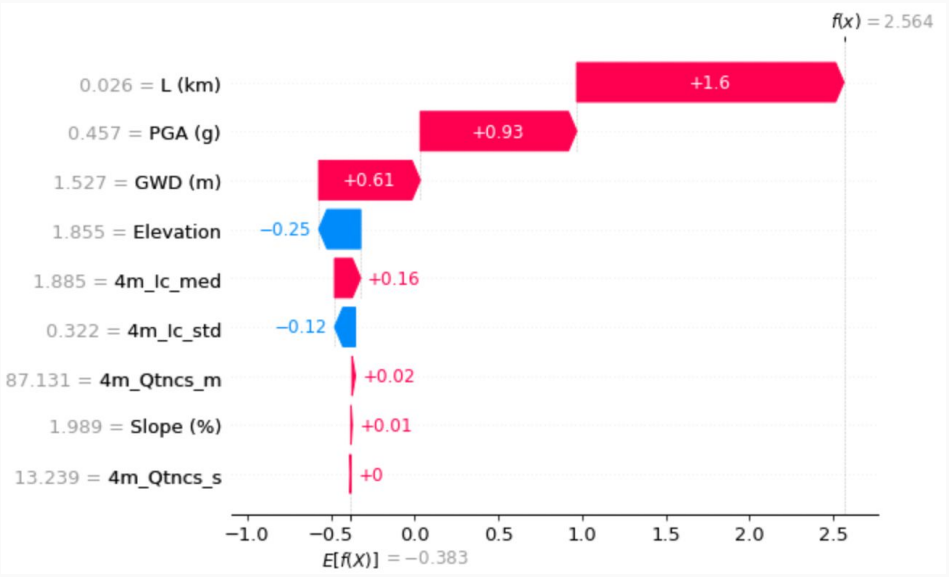
C: $v(\{A,B,C\}) - v(\{A,B\}) = 100 - 60 = 40$

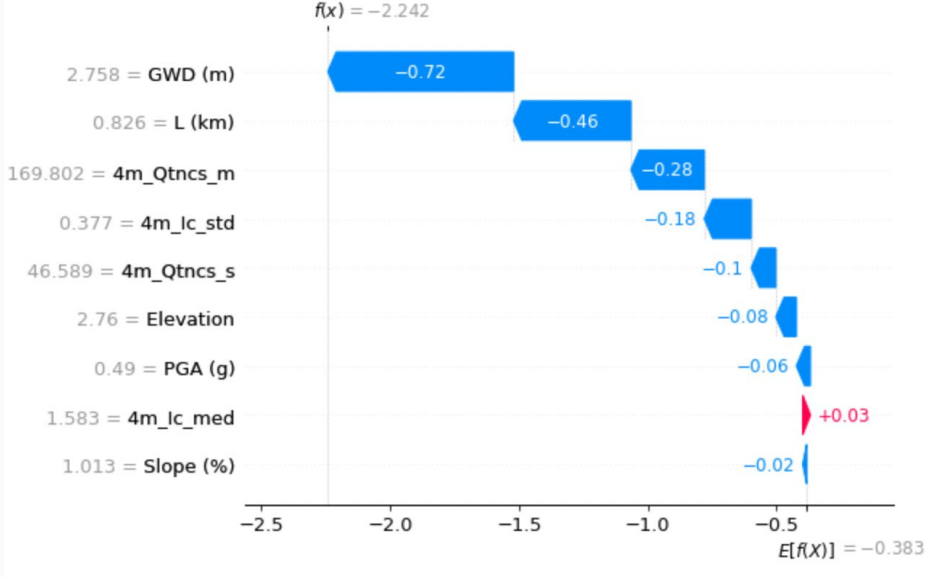
$v(\{\}) = 0$
$v(\{A\}) = 10$
$v(\{B\}) = 20$
$v(\{C\}) = 30$
$v(\{A,B\}) = 60$
$v(\{B,C\}) = 70$
$v(\{A,C\}) = 90$
$v(\{A,B,C\}) = 100$

$\{\} \rightarrow \{A\} \rightarrow \{A, B\} \rightarrow \{A, B, C\} \,||\, A = 10, B = 50, C = 40$
$\{\} \rightarrow \{A\} \rightarrow \{A, C\} \rightarrow \{A, B, C\} \,||\, A = 10, B = 10, C = 80$
$\{\} \rightarrow \{B\} \rightarrow \{A, B\} \rightarrow \{A, B, C\} \,||\, A = 40, B = 20, C = 40$
$\{\} \rightarrow \{B\} \rightarrow \{B, C\} \rightarrow \{A, B, C\} \,||\, A = 30, B = 20, C = 50$
$\{\} \rightarrow \{C\} \rightarrow \{B, C\} \rightarrow \{A, B, C\} \,||\, A = 30, B = 40, C = 30$
$\{\} \rightarrow \{C\} \rightarrow \{A, C\} \rightarrow \{A, B, C\} \,||\, A = 60, B = 10, C = 30$

$$A_{avg} = 30, B_{avg} = 25, C_{avg} = 45$$

Random Forest post-hoc explanation

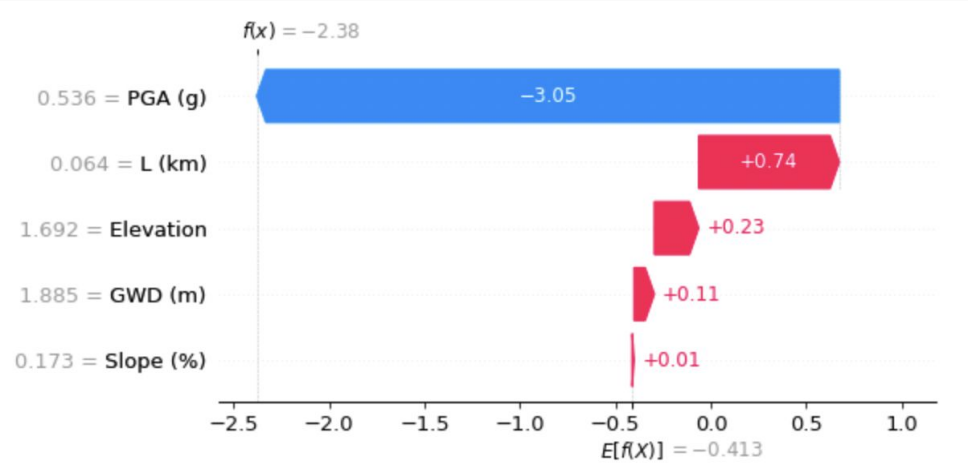




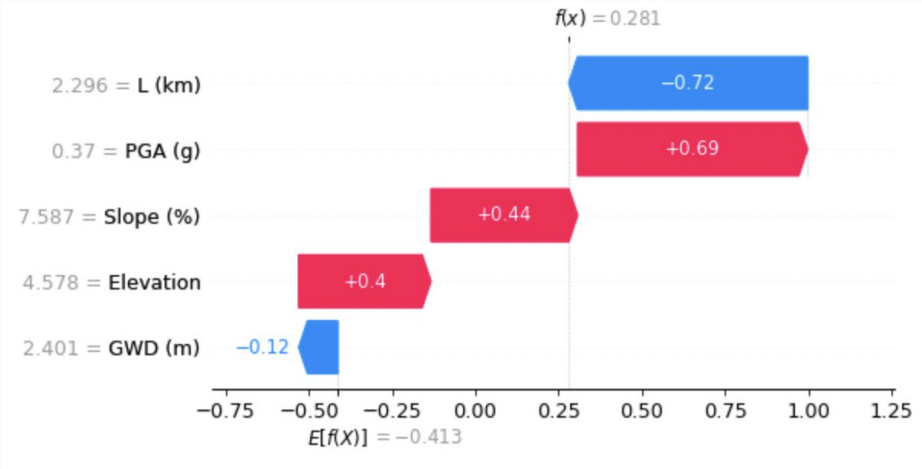
Lateral spreading - Prob (Lat spread) = 90%

No lateral spreading - Prob (Lat spread) = 7%

Incorrect learning

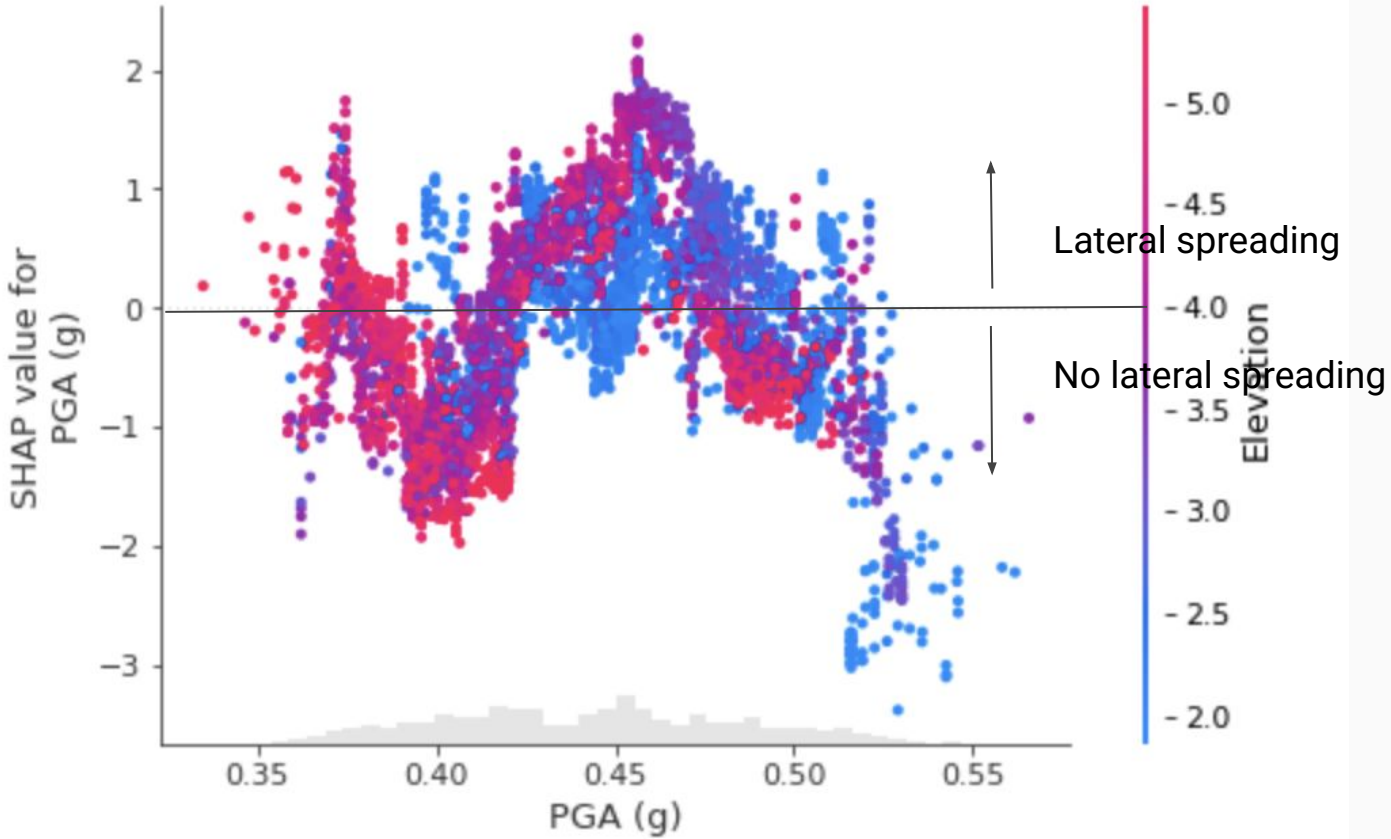


Incorrectly predicting no lateral spreading
Prob (Lat spread) = 8%

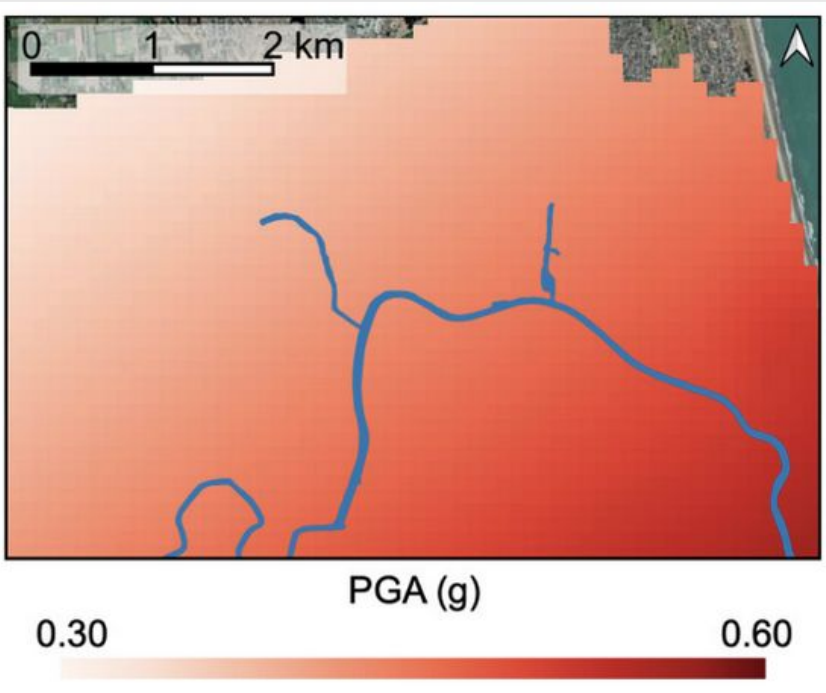


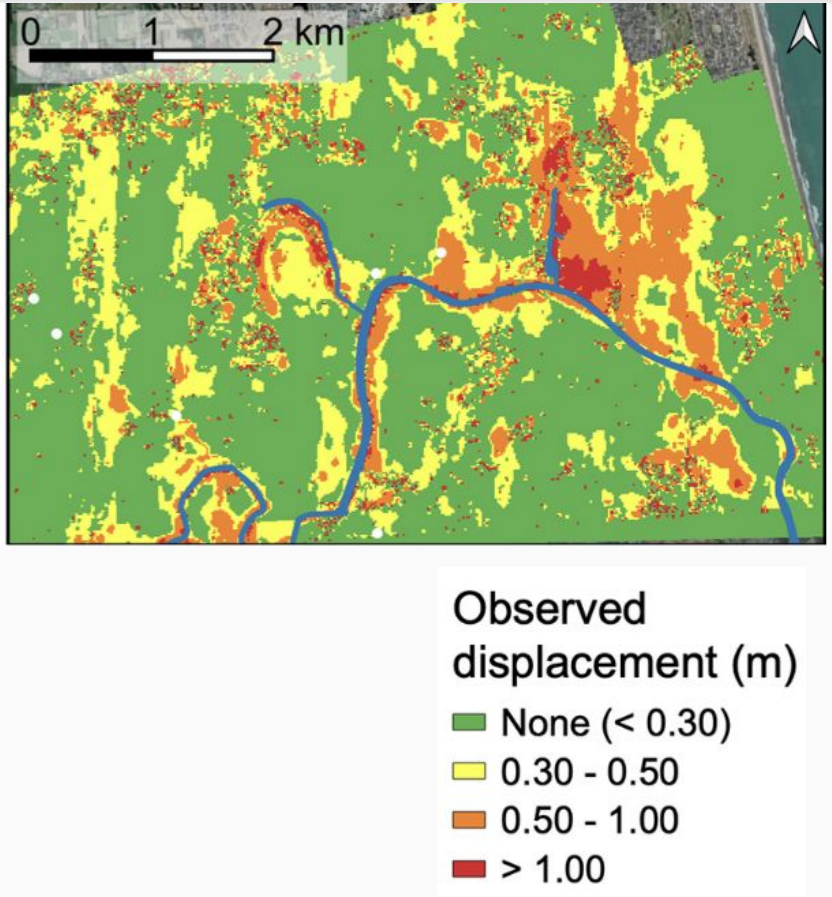
Incorrectly predicting lateral spreading
Prob (Lat spread) = 53%

Why PGA has a bad influence?



Bad learning of PGA relation





Multi-Layer Perceptron

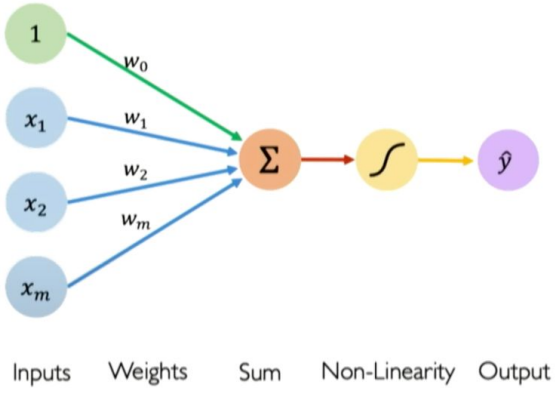
Now let's try with MLP

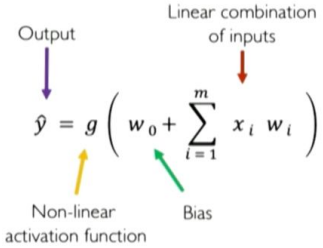
A perceptron computes:

$$z = \mathbf{w}^T \mathbf{x} + b = \sum_{i=1}^{n} w_i x_i + b$$

$$\hat{y} = g(z)$$

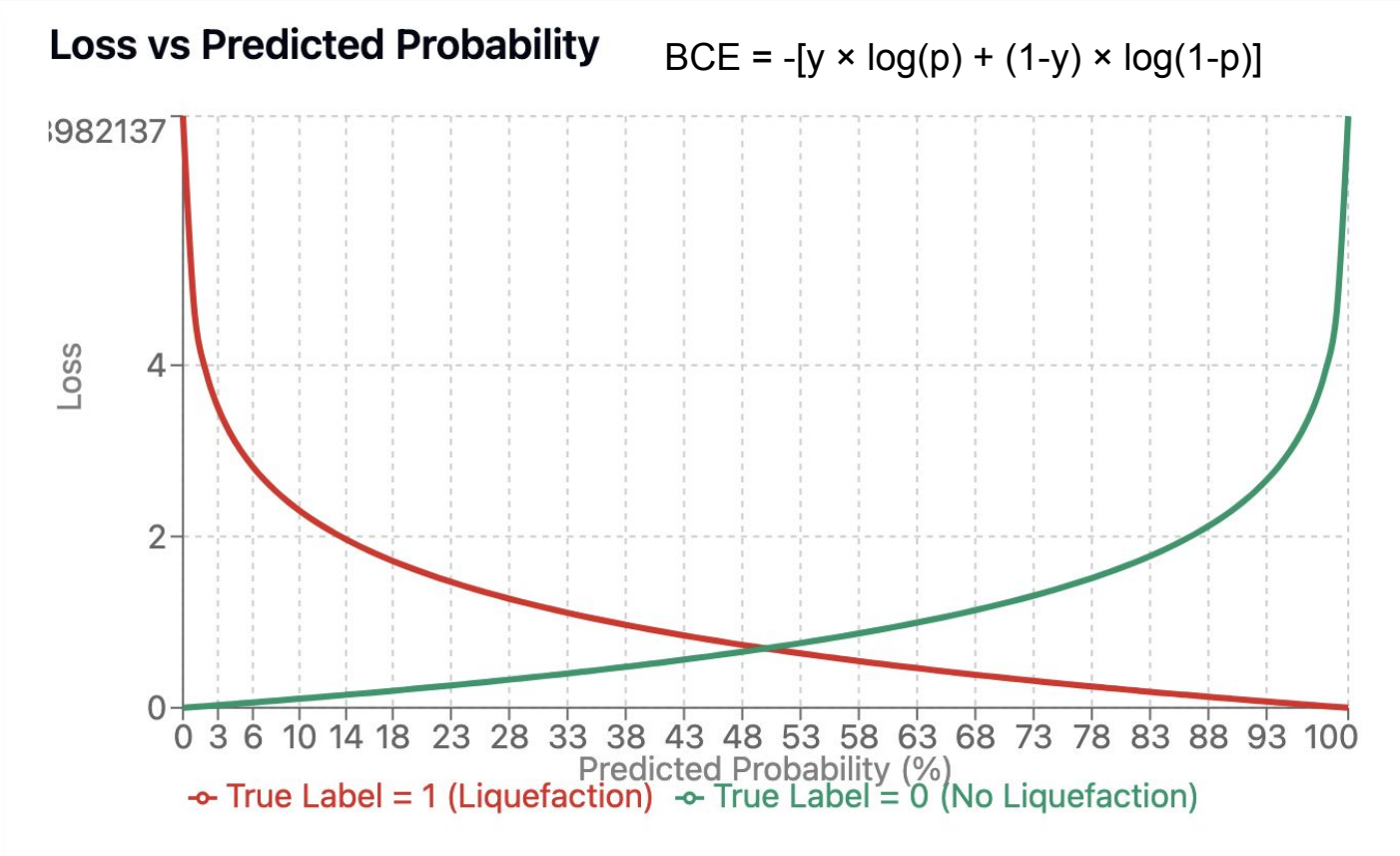
where g is the activation function.



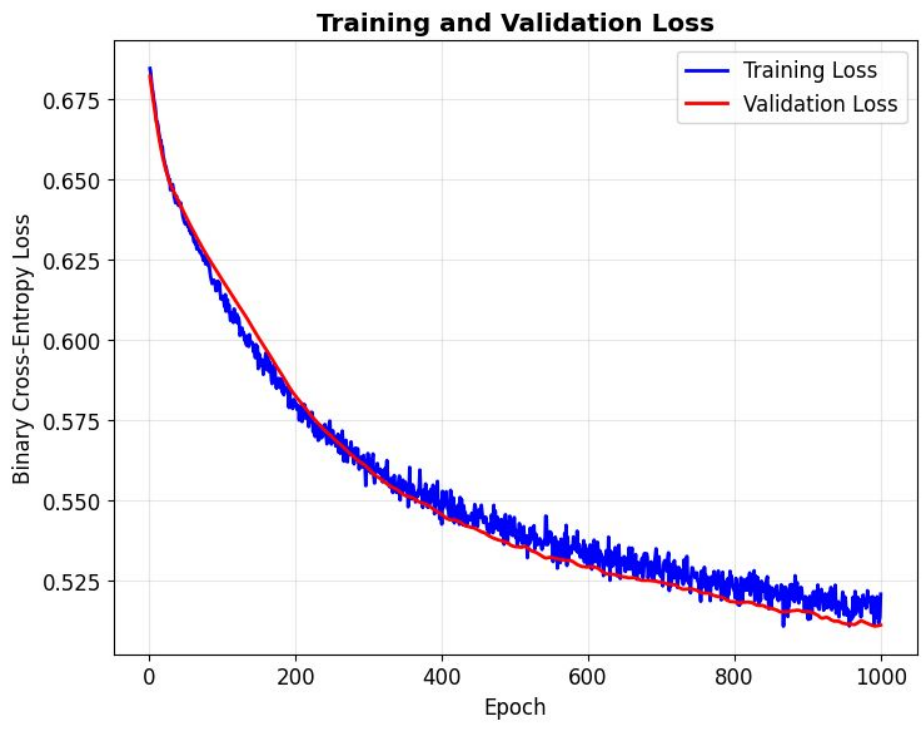


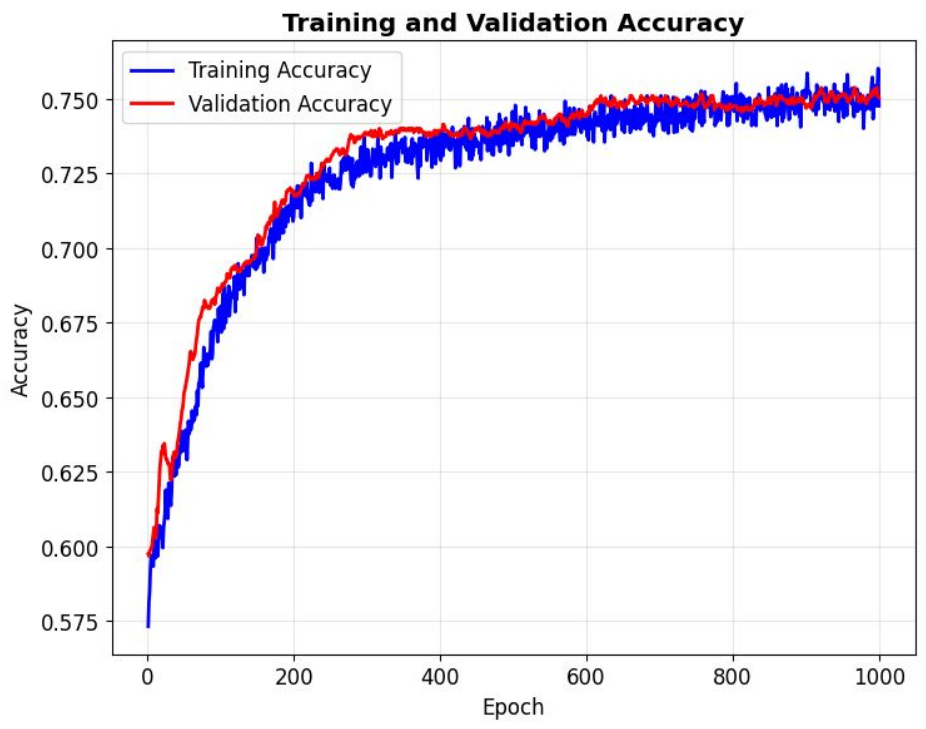
Perceptron architecture

Define a misfit (loss)

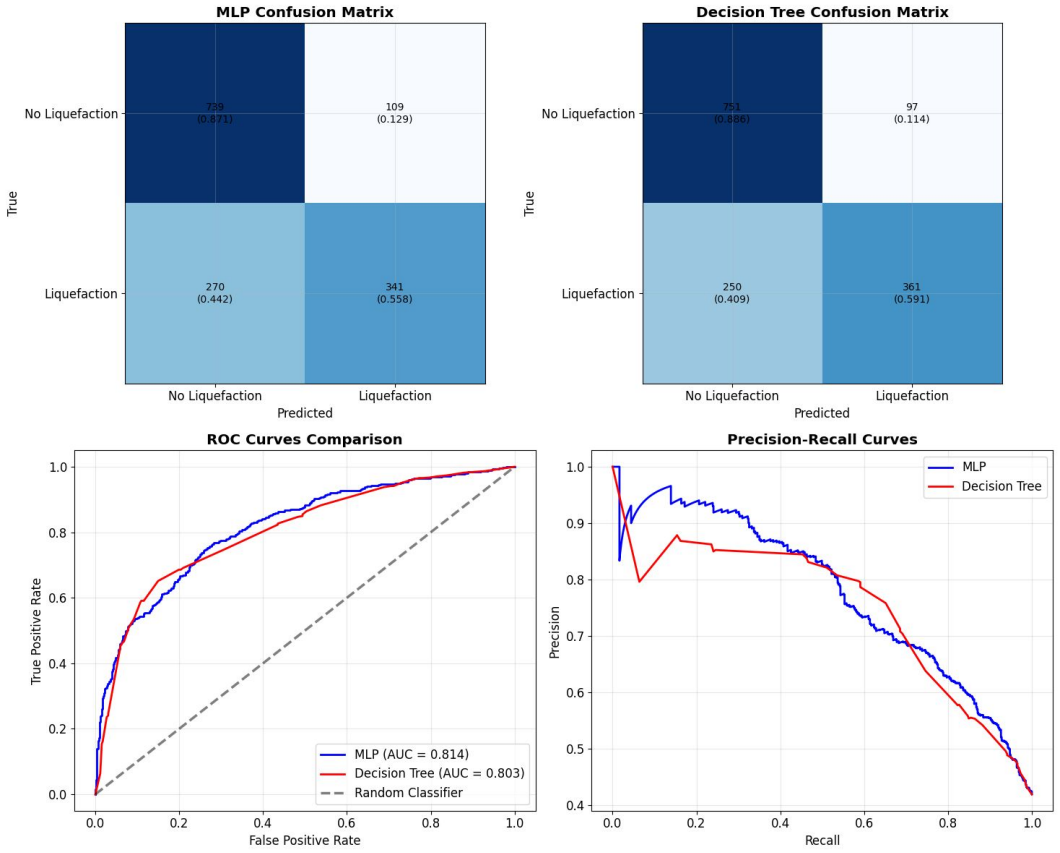


Training vs validation





MLP results


MLP Confusion Matrix
No Liquefaction
Liquefaction
True
739
(0.871)
109
(0.129)
270
(0.442)
341
(0.558)
No Liquefaction
Liquefaction
Predicted
Decision Tree Confusion Matrix
No Liquefaction
Liquefaction
True
751
(0.886)
97
(0.114)
250
(0.409)
361
(0.591)
No Liquefaction
Liquefaction
Predicted
ROC Curves Comparison
True Positive Rate
False Positive Rate
MLP (AUC = 0.814)
Decision Tree (AUC = 0.803)
Random Classifier
Precision-Recall Curves
Precision
Recall
MLP
Decision Tree

Deeper/Larger Networks are better!